TECHNICAL REPORT
NATICK/TR-15/020

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USE OF BODY ARMOR PROTECTION LEVELS WITH SQUAD AUTOMATIC WEAPON FIGHTING LOAD IMPACTS SOLDIER PERFORMANCE, MOBILITY, AND POSTURAL CONTROL

by

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May 2015

Final Report
January 2012 – July 2013

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U.S. Army Natick Soldier Research, Development and Engineering Center
Natick, Massachusetts 01760-5020

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
15-05-2015	Final	January 2012- July 2013

4. TITLE AND SUBTITLE
USE OF BODY ARMOR PROTECTION LEVELS WITH SQUAD AUTOMATIC WEAPON FIGHTING LOAD IMPACTS SOLDIER PERFORMANCE, MOBILITY, AND POSTURAL CONTROL

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Kari L. Loverro*, Tyler N. Brown, and Jeffrey M. Schiffman

5d. PROJECT NUMBER

5e. TASK NUMBER
WS-110043

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Natick Soldier Research, Development and Engineering Center
ATTN: RDNS-WSH-B
Kansas St., Natick, MA 01760-5020

8. PERFORMING ORGANIZATION REPORT NUMBER
NATICK/TR-15/020

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES
*Oak Ridge Institute for Science and Education (ORISE), Oak Ridge Associated Universities (ORAU) Maryland, 4692 Millennium Drive , Suite 101, Belcamp, MD 21017

14. ABSTRACT
This report details a 2012-13 study, performed by the Natick Soldier Research, Development and Engineering Center, to examine the effects of wearing soft body armor and fighting loads on Soldier performance, mobility, and postural control. In addition to wearing body armor for protection against fragmentation or ballistic threats, Soldiers are encumbered with a fighting load that typically includes a weapon, helmet, ammunition, fighting load carrier and other essentials. Recently, the Army issued guidance on levels of body armor that can be worn during tactical operations. While increased levels of armor increase in ballistic protection of Soldiers, they also increase the weight carried. Previous research has shown that heavy loads from back packs diminish Soldier performance and mobility; however, little research has examined body armor and fighting load alone. Therefore, the main purpose of this evaluation was to examine how increases in body armor protection levels with a fighting load impacted Soldiers' performance, mobility and postural control. Mobility and postural control were also examined without a fighting load. Results indicate that it is the addition of the fighting load that decreases mobility and postural control, while only large increases in body armor protection levels decrease performance. Further research on body armor protection levels with a fighting load is recommended to examine more challenging and unconstrained mobility and agility task, in the presence of cognitive performance tasks.

15. SUBJECT TERMS
MOTION COMPARISON LOAD CARRIAGE POSTURE(PHYSIOLOGY) MOTOR PERFORMANCE
AGILITY BODY ARMOR LOAD-CARRYING TEST AND EVALUATION PERFORMANCE(HUMAN)
MOBILITY LOAD BEARING ARMY PERSONNEL PROTECTIVE CLOTHING
WALKING LOADS(FORCES) OBSTACLE COURSE PROTECTIVE EQUIPMENT
BALLISTICS BIOMECHANICS POSTURAL CONTROL PPE(PERSONAL PROTECTIVE EQUIPMENT)

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Tyler N. Brown
U	U	U	SAR	36	**19b. TELEPHONE NUMBER** *(include area code)* 508-233-5705

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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ACKNOWLEDGEMENTS

The evaluation reported was carried out by personnel of the Biomechanics Team, Warfighter Science, Technology, and Applied Research Directorate, Natick Soldier Research, Development, and Engineering Center (NSRDEC).

The authors are most grateful to Dr. Carolyn Bensel, Dr. Leif Hasselquist, Mr. Richard Haddad, and Mr. Caleb Singer of NSRDEC for their support and guidance in preparing for and executing the evaluation. The authors also wish to thank Megan Coyne and Jon Kaplan for their assistance in the conduct and analysis of the evaluation.

Special recognition is owed to the volunteers, who were enlisted men assigned to Headquarters Research and Development Detachment, Natick Soldier Systems Center, Natick, MA.

USE OF BODY ARMOR PROTECTION LEVELS WITH SQUAD AUTOMATIC WEAPON FIGHTING LOAD IMPACTS SOLDIER PERFORMANCE, MOBILITY, AND POSTURAL CONTROL

1.0 INTRODUCTION

This report details work performed by the Natick Soldier Research, Development and Engineering Center (NSRDEC) from January of 2012 to July of 2013 to examine the effects of body armor and fighting loads on Soldier performance, mobility, and postural control.

During combat, Soldiers wear personal protective equipment (PPE), in part for protection against fragmentation or ballistic threats. Depending on the nature and threat of fragmentation or ballistic injury during operations, different combinations of body armor and ballistic plates may be worn. Previously, the US Army established guidelines for body armor protection levels (BAPLs) depending on the type of protection required (Memo, 2011). The BAPLs start with no armor (BAPL 0) and incrementally increase in protection. The first level is soft armor, either the plate carrier (PC) (BAPL 1a, 2.7 kg) or the improved outer tactical vest (IOTV) (BAPL 1b, 4.8 kg). The next step is addition of front and back ballistic plates to either BAPL 1a (BAPL 2, 8.4 kg) or to BAPL 1b (BAPL 4, 9.8 kg). Finally side ballistic plates can be added to either BAPL 2 (BAPL 3, 10.0 kg) or to BAPL 4 (BAPL 5, 12.1 kg).

Body armor, however, is just one component of the Soldier's total body-borne load. During tactical operations, in addition to body armor, Soldiers are encumbered with a combat load that typically includes a weapon, helmet, ammunition, fighting load carrier (FLC), rucksack, and other essentials. Depending on the operation, the combat load may add between 9 kg (such as for a fighting load) and 60 kg (such as for an emergency approach march load) of weight in addition to the body armor worn by the Soldier (FM 21-18, 1990). Short duration missions where enemy contact may be expected, require the Soldier to remain mobile. Thus, Soldiers strive to keep the fighting load weight to a minimum while also taking into account mission requirements. The US Army recommends that the fighting load including body-worn armor not exceed 21 kg to ensure that Soldier performance and agility are not impacted by the constraints of load (FM 21-18, 1990).

In order to optimize Soldier performance during dismounted operations, research has focused on body-borne weight to better understand the effects of loading the Soldier. One measure of performance includes examining the time to complete physical maneuvers to examine load carriage effects. For example, body armor, combat loads, and other PPE both individually and collectively have been examined to determine if increased load has detrimental effects on performance. Previous experimental evidence has shown that the additional mass of both a combat load (Knapik et al. 2004) and body armor (Hasselquist et al., 2012) decrease performance (e.g., long distance runs, short sprints, agility runs, and obstacle courses) (Knapik, 2004). Recently, Peoples et al., (2010) compared the impact of different BAPLs with a fighting load on Soldier performance during a repeated 5 m rush (i.e., a short sprint). While it took significantly longer to complete the rush task in all weighted body armor conditions compared to the no body armor condition, no significant differences in rush time were evident between closely weighted body armor conditions (Peoples et al., 2010). This reduction in performance

may stem from significant biomechanical alterations, such as decreased lower limb joint range of motion (Attwells et al., 2006) and/or postural alterations, such as maintenance of balance control (Schiffman et al., 2006; Sell et al., 2013) that occur during load carriage.

Measuring Soldier performance in terms of time to complete physical maneuvers reports on only part of the effect that load has on a Soldier's ability to complete their missions effectively. It is also important to quantify the changes in mobility (i.e., joint range of motion) and postural control (i.e., balance control) during load carriage. Biomechanical analysis that includes temporal, kinematic, or kinetic related measures may facilitate this understanding. Historically though, load carriage research has limited its biomechanical assessment of Soldier tasks to continuous straight-line ambulation (Attwells et al. 2006; Hasselquist et al. 2012) or static standing (Schiffman et al. 2006; Rugelj et al. 2011). Some research exists about how added mass, specifically body armor and fighting load, impacts Soldier mobility and postural control during common militarily relevant tasks. The addition of an anterior load (i.e., an FLC), for instance, significantly decreased mobility (Perry et al., 2010) and postural control (Reitdyk et al., 2010) during other common Soldier tasks including obstacle and step negotiation. Sell et al. (2013) reported that donning body armor diminished a Soldier's dynamic postural control while jumping over a hurdle. Still, additional research on the effects of body armor and fighting load is needed to address a full range of common military tasks including walking over hurdles, under low hanging obstacles, and across balance beams.

Based on the reported research literature, PPE, including body armor and a fighting load, has a detrimental effect on Soldiers' performance, mobility, and postural control. It is unknown, however, how increasing protection levels, which also increases body-borne weight and changes how the body is encumbered, may adversely impact Soldiers' performance, mobility, and postural control. Therefore, the main purpose of this evaluation was to examine how increases in BAPLs impacted Soldiers' performance, mobility, and postural control while wearing an FLC. It was hypothesized that the increase in BAPL on Soldiers wearing an FLC would decrease performance, mobility, and postural control (Hypothesis 1). Furthermore, as BAPL increased, these effects would intensify. The second purpose was to examine how addition of an FLC on Soldiers wearing armor impacted Soldiers' mobility and postural control at each BAPL. For this, it was hypothesized that for every BAPL, the addition of an FLC would decrease mobility and postural control (Hypothesis 2). The third purpose was to examine how wearing both armor and an FLC impacted Soldiers' performance, mobility, and postural control compared to wearing no armor and no FLC. It was hypothesized that the addition of any body armor with an FLC would decrease performance, mobility, and postural control (Hypothesis 3).

2.0 METHODS

This evaluation was performed in accordance with the NSRDEC Assurance for the Protection of Human Subjects (DoDA20124 dated 1 April 2008). The NSRDEC Human Subjects Research Determination Panel determined that this activity did not meet the regulatory definition of human subjects research, as defined by 32CFR219.102 (Definitions). Institutional Authority Approval was obtained before data collection took place.

2.1 Participants

Fifteen enlisted US Army male Soldiers volunteered and consented for the evaluation; however, one Soldier dropped out due to scheduling conflicts. Therefore, 14 males participated in the evaluation. The data of only 13 males (age 21.2 ± 2.5 years, height 1.8 ± 0.6 m, weight 89.8 ± 10.9 kg) were ultimately analyzed for this study, as one volunteer's data set was incomplete and subsequently excluded from analysis. Exclusion criteria included any lower extremity injuries that would inhibit the Soldier's ability to complete the study. The evaluation was completed at the Center for Military Biomechanics (Natick, MA).

2.2 Load Conditions

Five of the seven possible BAPLs were selected for inclusion in this evaluation (Table 1). Four (BAPLs 0, 1b, 3, and 5) of the five BAPL conditions evaluated were selected for analysis. BAPL 1a data were not analyzed in order to present concise preliminary findings to date. BAPLs 2 and BAPL 4 were not evaluated due to the close proximity in weight to BAPL 3 and BAPL 5, respectively. Furthermore, BAPL 5+, which includes wearing the nape pads, groin, neck, throat, and/or deltoid auxiliary protection, was not examined because these items may further constrain movement of the legs, arms, or head. If these accessories were added it would be difficult to discriminate whether differences were a result of the body armor or the accessories.

Table 1: *BAPLs available, evaluated, and analyzed.*

Level	Description	Data Collected	Data Analyzed	Body Armor Weight (kg)
BAPL 0	No Body Armor	Y	Y	0
BAPL 1a	PC w/soft armor only	Y	N	2.7
BAPL 1b	IOTV w/soft armor only	Y	Y	4.8
BAPL 2	PC w/front and back plates only	N	N	8.4
BAPL 3	PC w/front, back, and side plates	Y	Y	10.0
BAPL 4	IOTV w/front and back plates	N	N	9.8
BAPL 5	IOTV w/front, back, and side plates	Y	Y	12.1

Each Soldier participated in five data collection sessions over a 3-week period. During each session, data for one BAPL condition were collected. For the four BAPLs (1a, 1b, 3, and 5), the Soldiers performed each task wearing an FLC, which weighed 11 kg and was configured for the Squad Automatic Weapon (SAW) gunner unit position. The Soldiers also performed all but one of those tasks (the performance task) without the FLC to allow comparison between with and

without FLC conditions. FLC was not worn with BAPL 0. For all load conditions, including BAPL 0, Soldiers wore a helmet (1.5 kg) and boots (1.6 kg), and carried a mock M249 weapon (4.2 kg). The total weight of each load condition (including helmet, boots, weapon, and armor), without and with FLC, can be found in Table 2. Figures 1, 2, 3, and 4 show a Soldier carrying a weapon and wearing a helmet in each BAPL (1a, 1b, 3, and 5, respectively) both without and with the FLC.

Table 2: *Total weight (kg) of load configurations evaluated.*

	BAPL 0	BAPL 1a	BAPL 1b	BAPL 3	BAPL 5
No FLC	7.3	10.0	12.1	17.1	19.4
+FLC	n/a	21.0	23.1	28.1	30.4

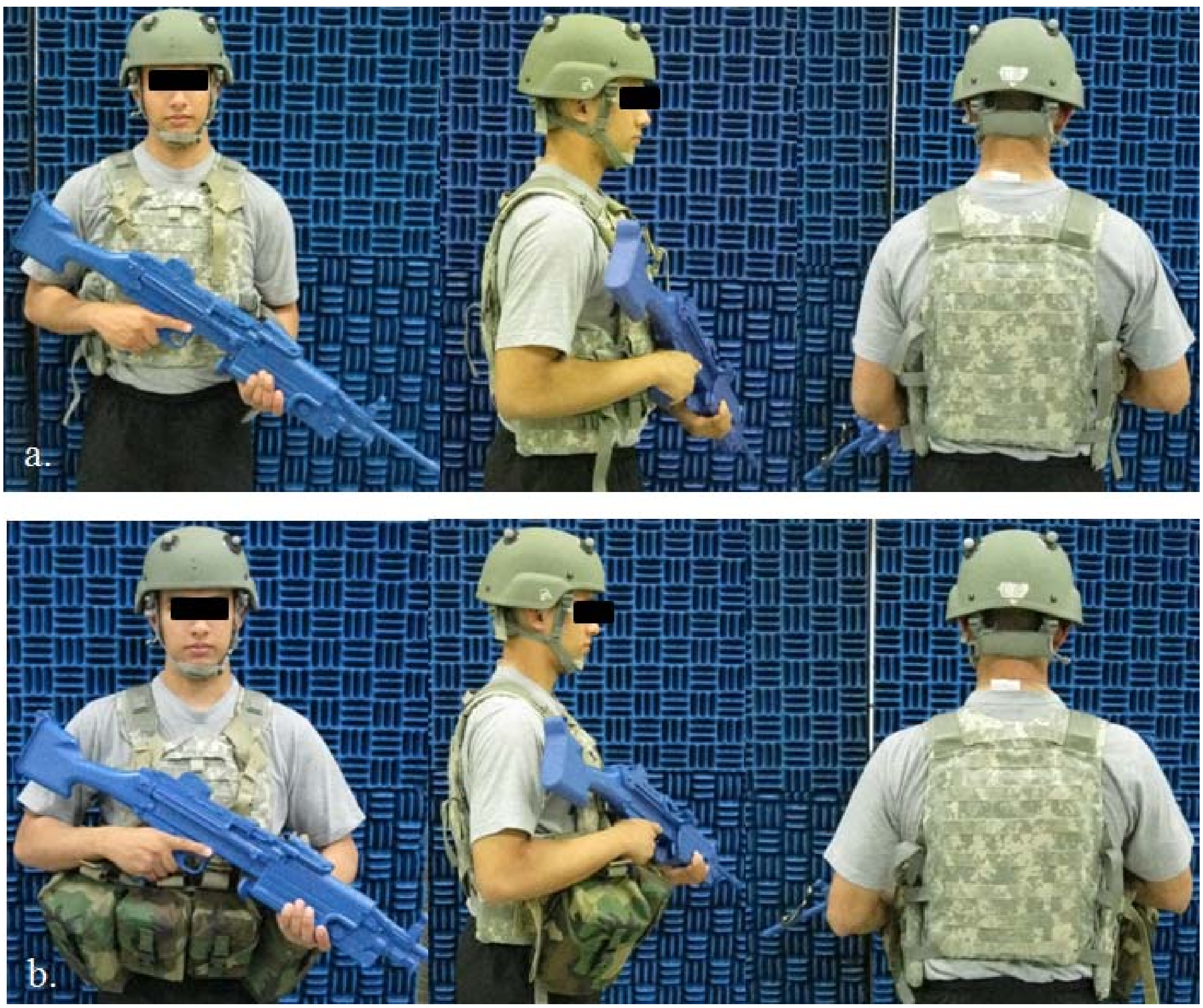


Figure 1*: BAPL 1a. (a) Without FLC; (b) With FLC.*

Figure 2: *BAPL 1b. (a) Without FLC; (b) With FLC.*

***Figure 3**: BAPL 3. (a) Without FLC; (b) With FLC.*

__Figure 4__: BAPL 5. (a) Without FLC); (b) With FLC.

2.3 Tasks

At each session, Soldiers completed one performance task, six mobility tasks, and one postural control task, but the data for three of the mobility tasks were not analyzed (Table 3) to present concise preliminary findings to date. The second hypothesis does not include the impact (of addition of an FLC with each BAPL) on performance tasks because Soldiers always wear fighting loads during performance tasks. Therefore, the performance task included no exercises with BAPL without an FLC, and the methods and results discussions in this report are presented in two groups: (1) performance task (testing of only two hypotheses) and (2) mobility and posture control tasks (testing of all three hypotheses).

Table 3: *Tasks performed and analyzed*

Task	Description	Type
30-m Rush	**30-m rushes 10 times**	**Performance**
Walk	**Overground walking**	**Mobility**
Walk over (30-cm)	**Step over an obstacle 30-cm high**	**Mobility**
Walk over (46-cm)	Step over an obstacle 46-cm high	Mobility
Walk over (61-cm)	Step over an obstacle 61-cm high	Mobility
Walk under (Shoulder Height)	**Duck under an obstacle at shoulder height**	**Mobility**
Walk under (Nose Height)	Duck under an obstacle at nose height	Mobility
Balance Beam	**Traverse a 15-cm-wide balance beam**	**Postural Control**

BOLD indicates data were analyzed.

2.3.1 Performance Task (30-m Rush)

2.3.1.1 Task Description

A 30-m rush task, to be completed as quickly and as safely as possible, was selected to examine Soldier performance. For the rush task, two padded gym mats (Mats A and B), separated by 30 m, were placed at either end of the hallway. Each Soldier started the task by lying prone on Mat A with the weapon aimed at Target A, located approximately 5 m behind Mat B, at the opposite end of the rushing area (Figure 5). Upon an auditory signal given by the investigator, a Soldier immediately stood up and ran to Mat B (Rush 1). Once there, the Soldier assumed the prone position and again acquired Target A. Once the Soldier acquired the target, he acknowledged by announcing “set”, then stood back up, turned (Turn 1), and rushed back to Mat A (Rush 2). At Mat A, the Soldier dropped to prone and acquired Target B, announced “set”, got back up, turned (Turn 2), and rushed back to Mat B (Rush 3). The Soldier repeated the rush-turn-rush cycle until a total of 10 successive rushes and 9 drops to prone and turns were performed. This task was performed after the mobility and postural control tasks to limit fatigue while performing the other tasks.

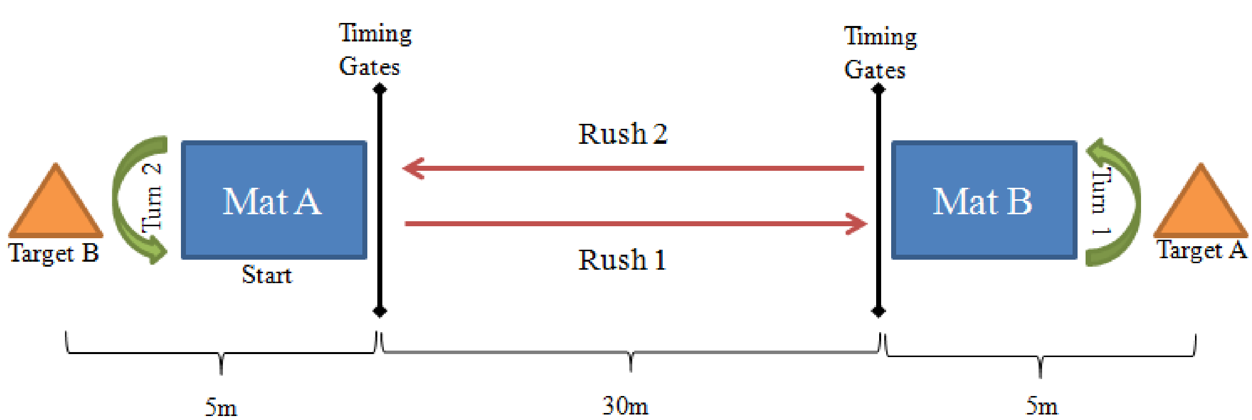


Figure 5*: The 30-m rush task, done for 10 total successive rushes and 9 drops to prone and turns.*

2.3.1.2 Data Collection and Analysis

To measure individual rush time, individual turn time, and total rush time during the rush task, timing gates (Bower Timing Systems, Draper, UT, USA) were placed 30 m apart in front of Mats A and B, and the targets were placed approximately 5 m behind the timing gates (Figure 5). Individual rush time was the time to run from one timing gate to the other (e.g., Rush 1). Individual turn time was the time to drop to prone, acquire the target, get back up, and turn (e.g., Turn 1). Total rush time was the time to complete all 10 rushes and all 9 turns. Dependent variables submitted for analysis were average individual rush time, the average time of the 10 rushes for each Soldier, average individual turn time, the average time of the 9 turns for each Soldier, and total rush time for each Soldier.

2.3.2 Mobility and Postural Control Tasks

2.3.2.1 Task Description

Soldiers completed five successful trials for each of the six mobility tasks and the one postural control task during every testing session. Three mobility tasks and the postural control task were selected for analysis (Table 3). The mobility tasks analyzed included the unobstructed overground walking (*walk)* task, walking over a 30 cm obstacle task (*walk over*), and ducking under a shoulder height obstacle (*walk under*) task. The postural control task was the balance beam.

For each mobility task, participants walked (1.3 m/s ± 5%) across a 10-m walkway. For the walk task, participants walked across an unobstructed walkway. For the walk over task, participants stepped over a 30-cm obstacle placed approximately 5 m from the start of the walkway. For the walk under task, participants ducked under an obstacle suspended from the ceiling at their shoulder height placed approximately 5 m from the start of the walkway. For both the walk over and under tasks, the obstacle was easily movable (e.g., from contact by the participant) to prevent tripping and falling during testing.

The balance beam task used a wooden balance beam that was 15 cm wide, 183 cm long, and 30 cm high. The balance beam was also placed in the middle of the walkway, but approximately 4.5 m from the Soldier’s starting position. A successful trial was defined as the Soldier walking at the proper speed while placing his dominant foot just prior to the beam, stepping onto the beam with his non-dominant foot, traversing the beam without loss of balance, and stepping off the beam.

2.3.2.2 Data Collection and Measurements

A 12-camera (Oqus Qualysis AB, Gothenburg, Sweden) motion capture system recorded the 3D trajectories of markers placed on the trunk and lower extremity. Specifically, clusters of four markers, joined by a rigid plastic plate, were secured on eight segments (bilateral lateral thigh, shank, and foot, and pelvis and torso) using double sided and athletic tape wrapped around the segment. The thigh and pelvis clusters were placed over tight fitting spandex shorts, the chest cluster was placed on the back of the body armor, and the foot clusters were placed on the hard soled heel portion of the shoe. Additionally, calibration markers were created by digitizing pre-determined anatomical landmarks on bilateral foot (first/fifth metatarsal head), shank (medial/lateral malleolus), and thigh (medial/lateral epicondyle and greater trochanter) and pelvis

(right/left anterior and posterior iliac spine and right/left iliac crest) and trunk (right/left acromion processes) according to the technique of Leardini et al. (2005).

Following marker placement, participants stood in a neutral (static) position, and two high speed (120 Hz) video recordings were taken, one with the volunteers wearing the fighting load (+FL) and one without the fighting load (No FL). Using both the digitized landmarks and static recordings a kinematic model was created in Visual 3D (v4.96, C-Motion, Germantown, MD) for both the +FL and No FL conditions. For both kinematic models, the pelvis was defined with respect to the global (laboratory) coordinate system and assigned 6 (3 translational and 3 rotational) degrees of freedom (Wu et al., 2002). The trunk, knee, and ankle joint centers and associated orthogonal local segment (3 degrees of freedom) coordinate systems were defined in accordance with previous literature (Bell, Pedersen, & Brand, 1990; Grood & Suntay, 1983; Seay, Selbie, & Hamill, 2008; Wu et al., 2002). For the hip joint, a standing trial with circular motion between the pelvis and thigh was used to calculate a functional joint center with Visual 3D, from a method adapted from Schwartz and Rozumalski (2005).

For each trial, marker trajectories were low pass filtered with a fourth order Butterworth filter at a cut-off frequency of 6 Hz. For the walk and walk over tasks, Visual 3D processed the filtered marker trajectories at each time frame, and absolute joint rotations were calculated and expressed relative to the static posture for the trunk, hip, and knee. For the walk under task, only trunk rotations were calculated from the filtered marker trajectories. For all tasks, joint rotations were calculated for a single stride, which was defined as heel strike of the dominant limb to ipsilateral heel strike of the non-dominant limb. For the walk task, the stride was selected when the participant was in the middle of the walkway, whereas, for the walk over and under tasks, the stride selected was from heel strike immediately before the obstacle to the ipsilateral heel strike immediately after the obstacle. For the balance beam task, the trajectory of the COM in the horizontal plane was exported from the first HS on the balance beam to the next ipsilateral HS on the balance beam.

2.4 Statistical Analysis

Statistical analyses were accomplished using PSAW Statistics 18.0 (SPSS Inc., Chicago, IL, USA). Separate analyses were performed to test each of the three hypotheses stated. However, since the Hypothesis 2 was not tested for the performance task (i.e., no data collection for 30 m rushes without an FLC), no analysis was performed to examine how addition of an FLC to BAPLs impacted Soldiers' performance. The dependent variables for the rush task included individual rush and turn time and total rush time. For the walk and walk over tasks, the dependent variables included maximum trunk extension during the stride; trunk extension and hip and knee flexion angle at heel strike; and peak hip and knee flexion angle during stance of the dominant limb. For the walk under task, the dependent variable was maximum trunk flexion during the stride. Initial analysis revealed no significant trial effect for any dependent variable. Therefore, each dependent variable was averaged across trials for each Soldier to calculate a "participant-based mean". To examine the differences between the BAPLs with an FLC, a one-factor repeated measure analysis of variance (ANOVA) with three BAPLs (BAPL 1b+FLC, BAPL 3+FLC, and BAPL 5+FLC) was performed for each dependent variable for all tasks. To compare the effect of BAPLs with and without an FLC, a two-factor repeated measures ANOVA with three BAPLs (BAPL 1b, BAPL 3, and BAPL 5) and two fighting load conditions (+FLC

and no FLC) was performed for each dependent variable of the mobility and postural control tasks. To compare BAPL 0 to the BAPLs with fighting loads, a one-factor repeated measure ANOVA with four BAPLs (BAPL 0, BAPL 1b+FLC, BAPL 3+FLC, and BAPL 5+FLC) was performed for each dependent variable for all tasks. In analyses where sphericity was significant ($p < 0.05$), the Greenhouse-Geisser adjustment was applied to the degrees of freedom. Alpha was set at 0.05, and where statistically significant differences were observed, a step-up sequential Bonferroni correction was used (Hommel, 1988) for post-hoc analysis. Significant interaction effects were submitted to one-way ANOVAs stratified by fighting load and followed up with t-tests to test simple main effects.

3.0 RESULTS

3.1 Performance Task (30-m Rush)

3.1.1 Comparison of BAPLs with FLC Attached (Hypothesis 1)

As shown in Table 4,the analysis revealed a significant effect of BAPL+FLC for total rush time ($p = 0.017$) and individual rush time ($p = 0.037$). Pairwise comparisons found that it took significantly longer for the Soldiers to complete the total rush ($p = 0.008$) and individual rush ($p = 0.001$) while wearing BAPL 5+FLC, as compared to wearing BAPL 1b+FLC. There was no effect ($p > 0.005$) for BAPL+FLC on average turn time of the Soldiers.

***Table 4**: Mean (SD) of dependent variables for performance of 30-m rush task: Comparison within BAPLs with FLC.*

	BAPL 1b+FLC	BAPL 3+FLC	BAPL 5+FLC
Total Time (s)	113.2(15.6)	115.0(16.0)	119.4(16.5)*
Rush Time (s)	7.0(0.8)	7.1(0.8)	7.4(0.9)*
Turn Time (s)	4.9(1.0)	5.1(1.3)	5.3(1.3)

*Significant difference ($p < 0.05$) between BAPL 1b+FLC and BAPL 5+FLC

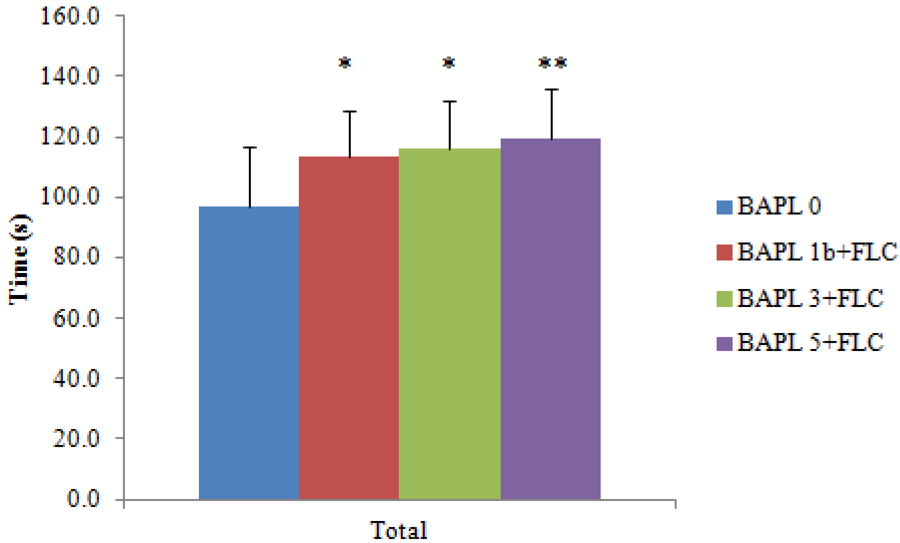
3.1.2 Comparison of No Armor to Each BAPL with FLC Attached (Hypothesis 3)

The analysis revealed a significant effect for total rush time ($p < 0.001$), average individual rush time ($p < 0.001$), and average individual turn time ($p = 0.005$) (Table 5). Specifically, the Soldiers had significantly faster total rush time and average individual rush time (both $p<0.001$) (Figures 6 and 7, respectively) when wearing BAPL 0 than when wearing BAPL 1b+FLC, BAPL 3+FLC, and BAPL 5+FLC. They also had significantly faster total rush time ($p = 0.008$) and average individual rush time ($p = 0.001$) when wearing BAPL 1b+FLC than when wearing BAPL 5+FLC. The Soldiers had significantly faster average individual turn time ($p = 0.007$) when wearing BAPL 0 than when wearing BAPL 5+FLC (Figure 8), but did not reach statistical significance when BAPL 0 was compared to BAPL 1b+FLC and to BAPL 3+FLC.

***Table 5:** Mean (SD) of dependent variables for performance of 30-m rush task: Comparison of BAPLs with FLC to BAPL 0.*

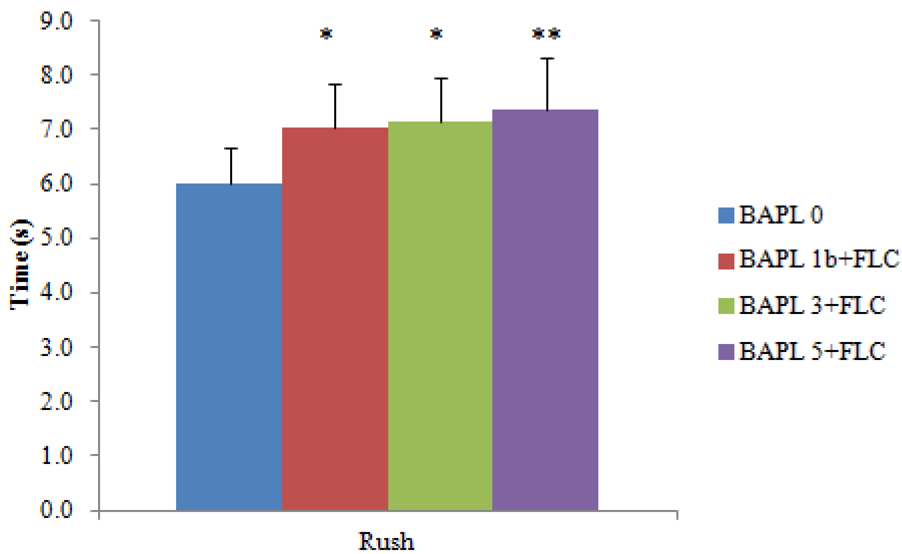
	BAPL 0	BAPL 1b+FLC	BAPL 3+FLC	BAPL 5+FLC
Total Time (s)	96.9(10.5)	113.2(15.6)*	115.0(16.0)*	119.4(16.5)*
Rush Time (s)	6.0(0.7)	7.0(0.8)*	7.1(0.8)*	7.4(0.9)*
Turn Time (s)	4.2(1.0)	4.9(1.0)	5.1(1.3)	5.3(1.3)*

*Significant difference ($p < 0.05$) between BAPL+FLC and BAPL 0



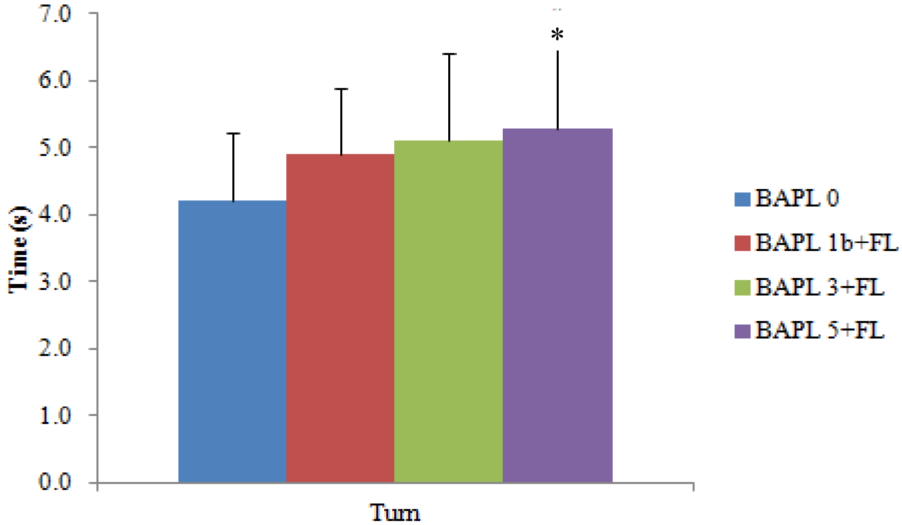
Error bars denote +1 SD.
*Significant difference ($p < 0.05$) between BAPL 0 and BAPL+FLC
**Significant difference between BAPL 5+FLC and BAPL 0 ($p<0.001$) and between BAPL 5+FLC and BAPL 1b+FLC ($p < 0.05$).

Figure 6*: Mean Total rush time for performance of 30-m rush*



Error bars denote +1 SD).
*Significant difference ($p < 0.05$) between BAPL 0 and BAPL+FLC.
**Significant difference between BAPL 5+FLC and BAPL 0 ($p<0.001$) and between BAPL 5+FLC and BAPL 1b+FLC ($p = 0.008$).

Figure 7: *Average individual rush time in performance of 30-m rush task.*



Error bars denote +1 SD.

*Significant effect for BAPL+FLC ($p < 0.05$) with a significant difference between BAPL 0 and BAPL5+FLC.

Figure 8: *Average individual turn time in performance of 30-m rush.*

3.2 Mobility and Postural Control Tasks

3.2.1 Comparison of BAPLs with FLC Attached (Hypothesis 1)

3.2.1.1 Walk

For the overground walk, the analysis revealed no significant effect ($p > 0.05$) for BAPL+FLC for any joint for any dependent variable (Table 6).

Table 6*: Mean (SD) of lower limb flexion angles at HS and PS in walk task. Comparison within BAPLs with FLC.*

Joint (°)	Variable	BAPL 1b+FLC	BAPL 3+FLC	BAPL 5+FLC
Trunk	HS	-0.5(3.1)	1.11(3.8)	1.5(4.1)
	Max Ext.	2.4(3.4)	3.6(4.0)	4.0(4.4)
Hip	HS	22.2(5.5)	23.2(4.8)	24.4(4.4)
	PS	-12.0(3.1)	-11.0(4.6)	-10.7(3.5)
Knee	HS	0.7(4.9)	0.4(6.1)	-0.1(5.4)
	PS	-17.0(3.7)	-17.4(5.1)	-18.0(4.0)

Note: No significant differences between any BAPL+FLC condition for any joint

3.2.1.2 Walk Over

For the walk over task, the analysis revealed no significant effect ($p > 0.05$) for BAPL+FLC for any joint for any dependent variable (Table 7).

__Table 7:__ Mean(SD) of lower limb flexion angle for walk over task: Comparison within BAPLs with FLC.

Angle (°)	Position	BAPL 1b+FLC	BAPL 3+FLC	BAPL 5+FLC
Trunk	HS	0.9(3.9)	1.5(4.0)	2.4(4.3)
	Max Ext.	4.5(4.7)	5.2(4.3)	5.9(4.2)
Hip	HS	25.8(4.1)	26.8(5.4)	27.0(6.2)
	PS	-13.9(4.7)	-12.7(4.9)	-12.0(5.2)
Knee	HS	0.1(6.2)	-0.7(7.0)	-2.3(8.9)
	PS	-19.4(4.5)	-20.5(6.2)	-20.5(5.6)

Note: No significant differences between any BAPL+FLC condition for any joint

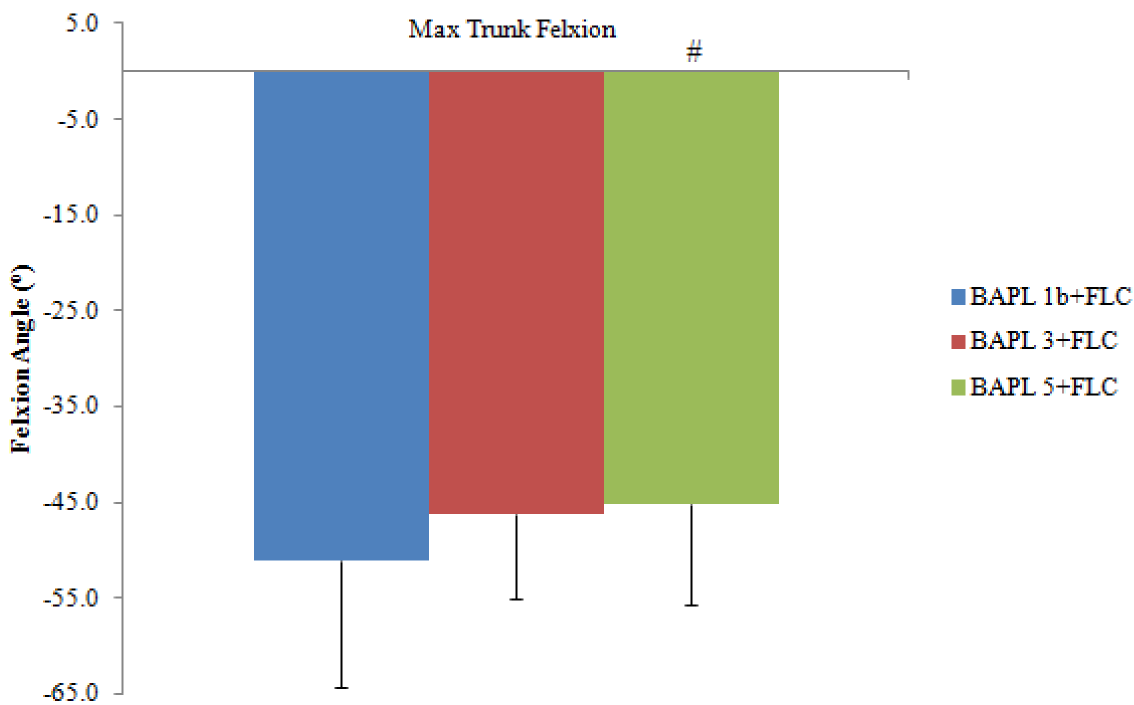
3.2.1.3 Walk Under Task

A main effect of BAPL+FLC ($p = 0.043$) was noted for the Soldiers' peak trunk flexion angle during the walk under task (Table 8). The pairwise comparisons, however, identified no significant differences ($p > 0.05$) in the Soldiers' peak trunk flexion between any condition (BAPL 1b+FLC, BAPL 3+FLC, and BAPL 5+FLC), although there was a trend toward significance ($p = 0.021$ $\eta^2 = 0.331$) in the lesser amount of peak flexion allowed by BAPL 5+FLC compared to BAPL 1b+FLC (Figure 8).

__Table 8:__ Mean (SD) of maximum trunk flexion for walk under task: Comparison within BAPLs with FLC.

Angle (°)	BAPL 1b +FLC	BAPL 3+FLC	BAPL 5 +FLC
Trunk	-51.1(13.1)	-46.3(8.8)	45.3(10.5) #

#Trend toward significant difference (p=0.021) between BAPL 5+FLC and BAPL 1b+FLC



Error bars denote +1 SD.

#Trend toward significant difference (p=0.063) between BAPL 5 with FLC and BAPL 1b with FLC

***Figure 9**: Means of maximum trunk flexion for walk under task: Comparison within BAPLs with FLC.*

3.2.1.4 Balance Beam

There was no significant effect ($p > 0.05$) for BAPL+FLC on Soldiers' HCOM during the balance beam task (Table 9).

Table 9: *Mean (SD) of HCOM motion for the balance beam task: Comparison within BAPLs with FLC.*

	BAPL 1b +FLC	BAPL 3+FLC	BAPL 5 +FLC
HCOM (cm)	7.3(2.6)	6.9(0.1)	7.7(3.1)

Note: No significant differences between any BAPL+FLC condition for HCOM

3.2.2 Interaction of BAPLs with and without FLC attached (Hypothesis 2)

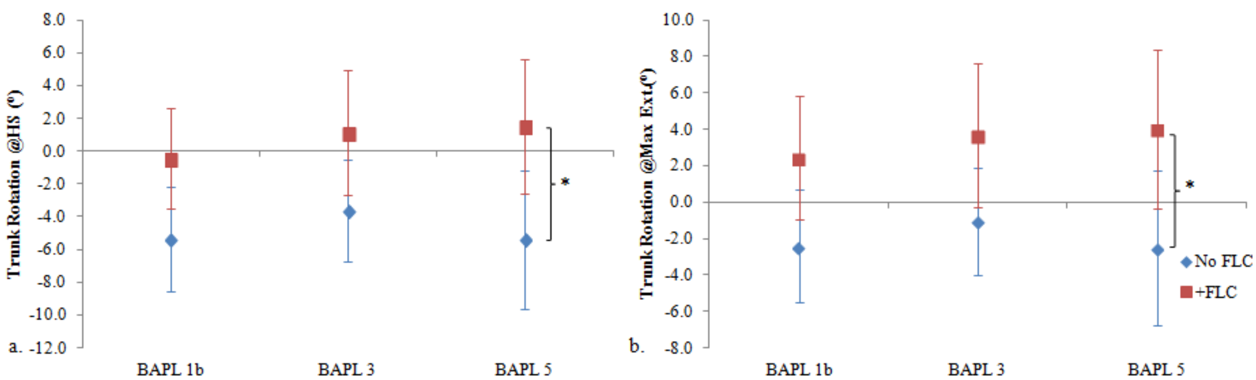
3.2.2.1 Walk

The results for all three movements under this task are presented in Table 10. During the walk task, the addition of the FLC significantly increased Soldiers' trunk extension at both HS ($p < 0.001$) and maximum extension ($p < 0.001$) (Figure 10). The Soldiers' hip flexion at heel strike ($p = 0.032$) and at PS ($p = 0.002$) was also significantly increased with the addition of the FLC, (Figure 11). Also at HS, there was a ($p = 0.027$) of the Soldiers' knee extension with the addition of the FLC, but no significance at PS (Table 10).

Table 10: *Means (SD) of lower limb flexion angles during walk task: Comparison within BAPLs with and without FLC.*

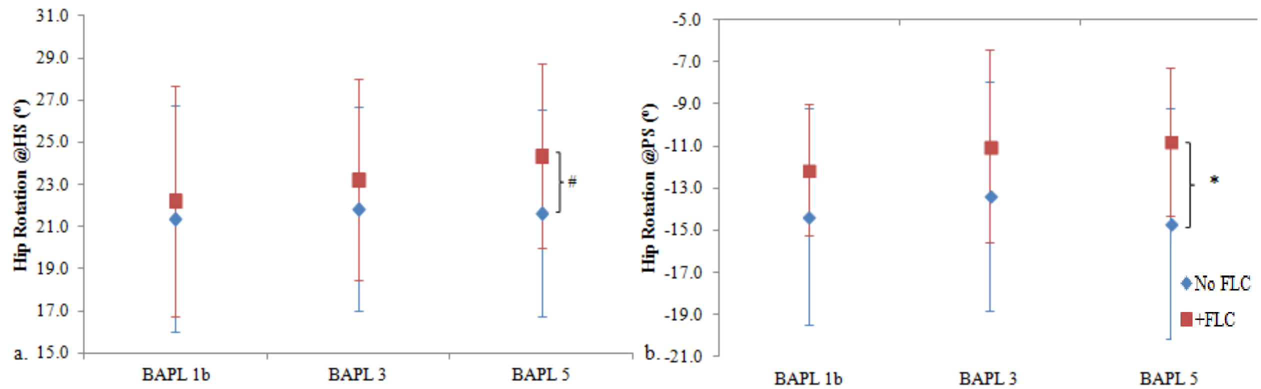
Angle (°)	Position	BAPL 1b		BAPL 3		BAPL 5	
		+FLC	No FLC	+FLC	No FLC	+FLC	No FLC
Trunk	HS*	-0.5(3.1)	-5.4(3.2)	1.11(3.8)	-3.7(3.1)	1.5(4.1)	-5.4(4.2)
	Max Ext.	2.4(3.4)	-2.4(3.1)	3.6(4.0)	-1.1(3.0)	4.0(4.4)	-2.5(4.3)
Hip	HS*	22.2(5.5)	21.4(5.4)	23.2(4.8)	21.8(4.8)	24.4(4.4)	21.7(4.9)
	PS*	-12.0(3.1)	-14.3(5.2)	-11.0(4.6)	-13.4(5.4)	-10.7(3.5)	-14.7(5.5)
Knee	HS*	0.7(4.9)	0.3(5.0)	0.4(6.1)	-0.3(5.4)	-0.1(5.4)	-1.7(4.9)
	PS	-17.0(3.7)	-17.3(4.4)	-17.4(5.1)	-18.1(4.6)	-18.0(4.0)	-18.8(3.7)

*Significant difference ($p < 0.05$) between with and without FLC conditions



Error bars denote 1 SD.
*Significant difference between with and without FLC

Figure 10: *Means of trunk flexion angles during walk task: Comparison of with and without FLC for each BAPL. (a) HS; (b) Maximum extension*



Error bars denote 1 SD.

*Significant difference between with and without FLC conditions

Figure 11: *Means of hip flexion angles during walk task: Comparison of with and without FLC. (a) HS; (b) PS*

3.2.2.2 Walk Over

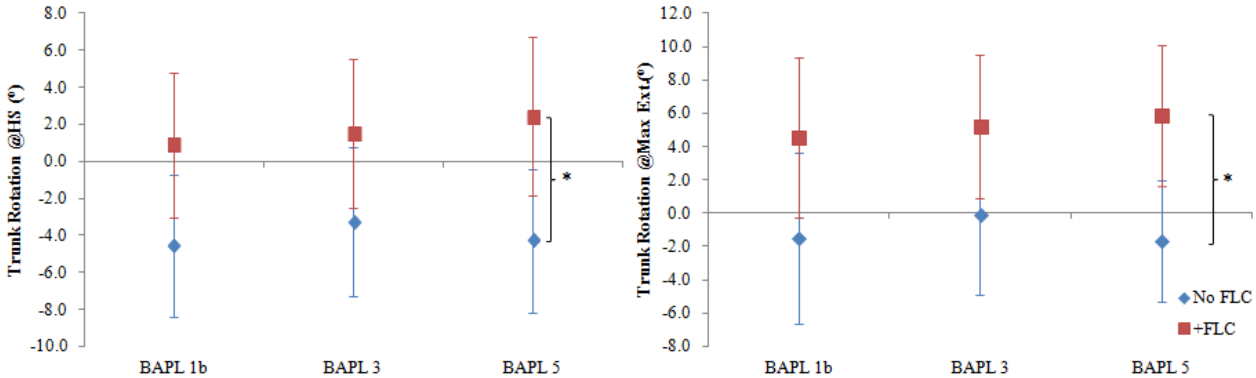
The results for all three joints during the walk over task, are presented in Table 11. The addition of the FLC significantly increased the Soldiers' trunk extension at both HS ($p < 0.001$) and maximum extension ($p < 0.001$) (Figure 12). Increased hip flexion was significant with the addition of the FLC at both HS ($p = 0.015$) and PS ($p = 0.018$), (Figure 13). The ANOVA revealed that at HS the knee had a significant effect ($p = 0.012$) for BAPL condition. The pairwise comparison revealed no significant differences between BAPL conditions, but there was a trend ($p = 0.057$) towards increased knee flexion for Soldiers while wearing BAPL 5 compared to BAPL 1b (Figure 14). BAPL and fighting load had no significant interactions ($p > 0.05$) at any joint for the Soldiers.

Table 11: *Means of (SD) lower limb flexion angles for walk over task: Comparison of with and without FLC for each BAPL.*

Angle (º)	Position	BAPL 1b		BAPL 3		BAPL 5	
		+FLC	No FLC	+FLC	No FLC	+FLC	No FLC
Trunk	HS*	0.9(3.9)	-4.6(3.9)	1.5(4.0)	-3.3(4.0)	2.4(4.3)	-4.3(3.9)
	Max Ext.*	4.5(4.7)	-1.5(5.1)	5.2(4.3)	-0.1(4.9)	5.9(4.2)	-1.7(3.6)
Hip	HS*	25.8(4.1)	23.3(5.4)	26.8(5.4)	24.7(5.0)	27.0(6.2)	24.2(7.1)
	PS*	-13.9(4.7)	-15.1(5.6)	-12.7(4.9)	-14.6(6.0)	-12.0(5.2)	-15.4(6.8)
Knee	HS^	0.1(6.2)	-0.8(6.4)	-0.7(7.0)	-2.2(6.2)	-2.3(8.9)	-4.3(7.7)
	PS	-19.4(4.5)	-19.0(5.1)	-20.5(6.2)	-19.9(4.9)	-20.5(5.6)	-20.0(6.2)

*Significant difference ($p < 0.05$) between with and without FLC conditions

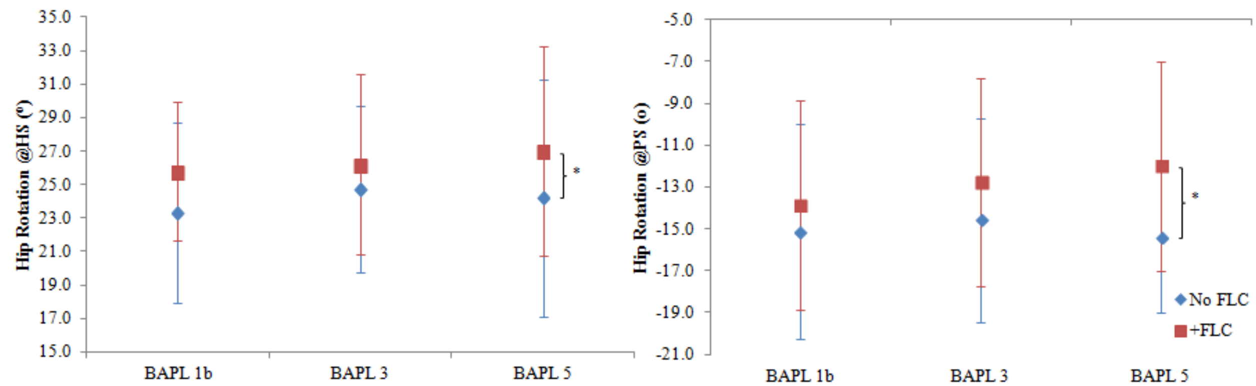
^Significant difference ($p < 0.05$) among BAPLs with a trend toward significant difference between BAPL 1b and BAPL 5



Error bars denote 1 SD.

*Significant difference between with and without FLC

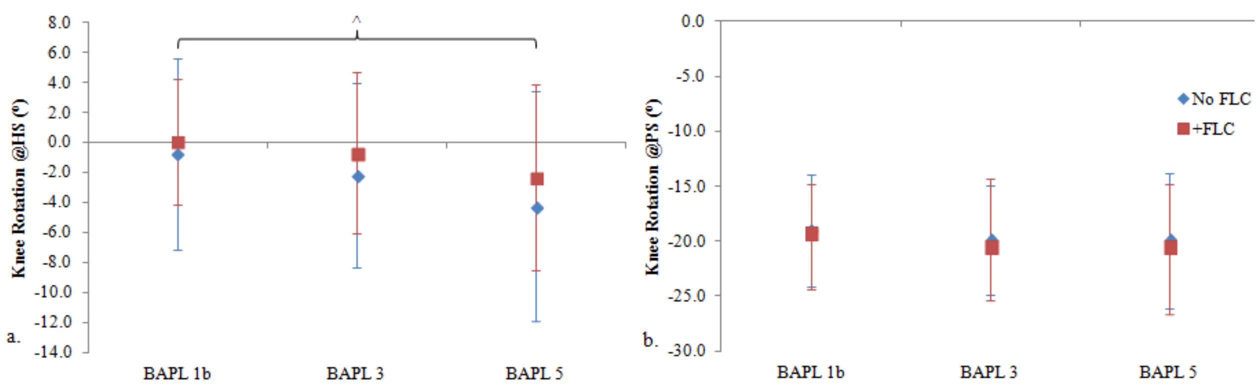
Figure 12: *Means for trunk flexion angles during walk over task: Comparison of with and without FLC. (a) HS; (b) PS*



Error bars denote 1 SD.

#Trend toward significant difference between with and without FLC

Figure 13: *Means for hip flexion angles during walk over task: Comparison of with and without FLC. (a) HS; (b) PS*



Error bars denote 1 SD.

^ Significant difference ($p < 0.05$) among BAPLs with a trend towards significant difference between BAPL 1b with FLC and BAPL 5 with FLC.

Figure 14: *Means for knee flexion angles during walk over task: Comparison of with and without FLC for each BAPL. (a) HS; (b) PS*

3.2.2.3 Walk Under Task

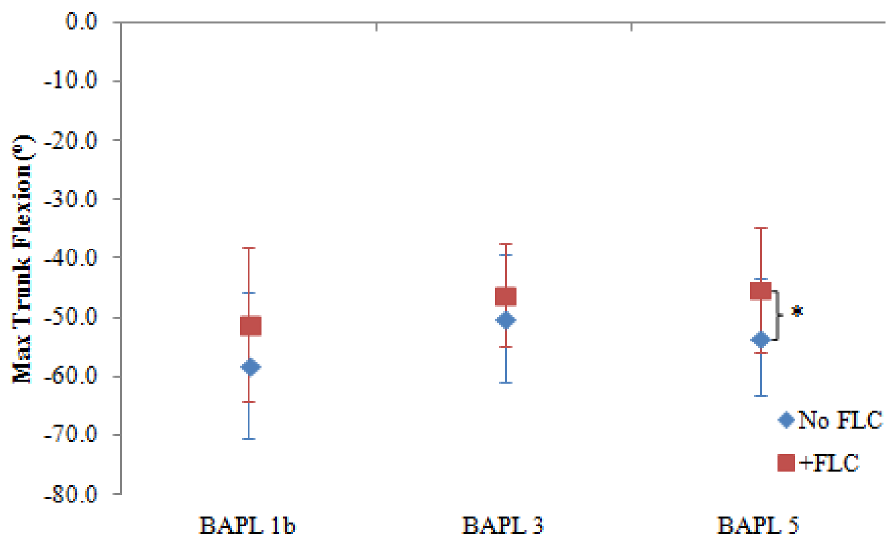
During the walk under task both the BAPL ($p = 0.020$) and the addition of the FLC ($p < 0.001$) significantly impacted the Soldiers' maximum trunk flexion. Pairwise comparisons of the BAPL conditions revealed no significant differences ($p > 0.05$) between any BAPLs. However, the addition of the FLC did significantly decrease the Soldiers' maximum trunk flexion ($p = 0.004$) (Table 12, Figure 15).

Table 12: *Mean(SD) maximum trunk flexion angles for walk under task: Comparison of with and without FLC for each BAPL.*

	BAPL 1b		BAPL 3		BAPL 5	
	+FLC	No FLC	+FLC	No FLC	+FLC	No FLC
Trunk (°)*^	-51.1(13.1)	-58.1(12.5)	-46.3(8.8)	-50.1(10.6)	45.3(10.5)	-53.3(9.9)

* Significant difference ($p < 0.05$) between with and without FLC for each BAPL.

^Significant difference ($p<0.05$) among BAPL conditions, although no significant pairwise comparisons.



Error bars denote 1 SD.
*Significant difference between with and without FLC

Figure 15: *Means of the trunk flexion for walk under task at shoulder height: Comparison of with and without FLC for each BAPL.*

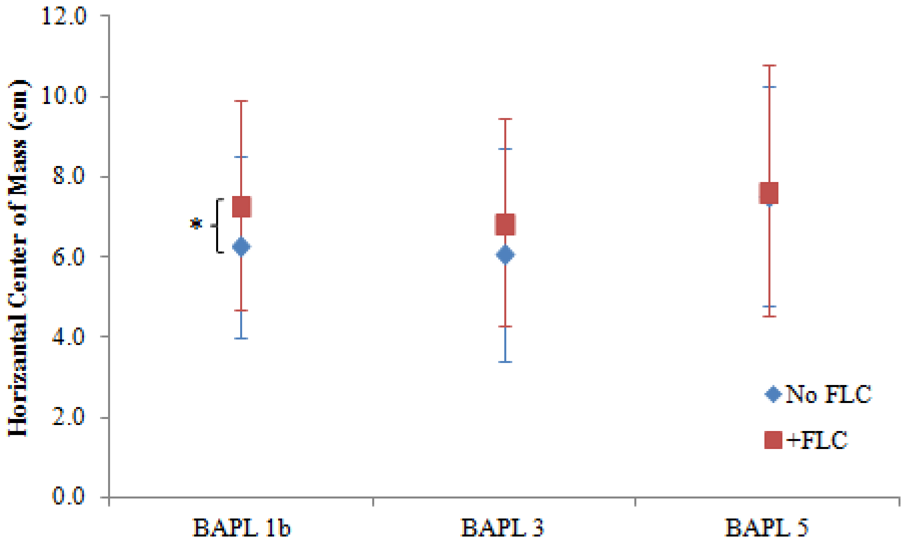
3.2.2.4 Balance Beam

The analysis revealed a significant main effect for FLC ($p = 0.004$). Specifically, there was reduction of the Soldiers' HCOM with no FLC compared to with the FLC when Soldiers traversed the beam (Table 13, Figure 16).

Table 13: *Means(SD) of HCOM displacement on balance beam: Comparison with and without FLC for each BAPL.*

	BAPL 1b		BAPL 3		BAPL 5	
	+FLC	No FLC	+FLC	No FLC	+FLC	No FLC
HCOM (cm)*	7.3(2.6)	6.3(2.3)	6.9(0.1)	6.1(2.7)	7.7(3.1)	7.5(2.7)

*Significant difference ($p < 0.05$) between with and without FLC for each BAPL



Error bars denote 1 SD.
*Significant difference between with and without FLC.

Figure 16: *Means of the HCOM displacement on balance beam: Comparison with and without FLC for each BAPL.*

3.2.3 Comparison of No Armor to Each BAPL with FLC (Hypothesis 3)

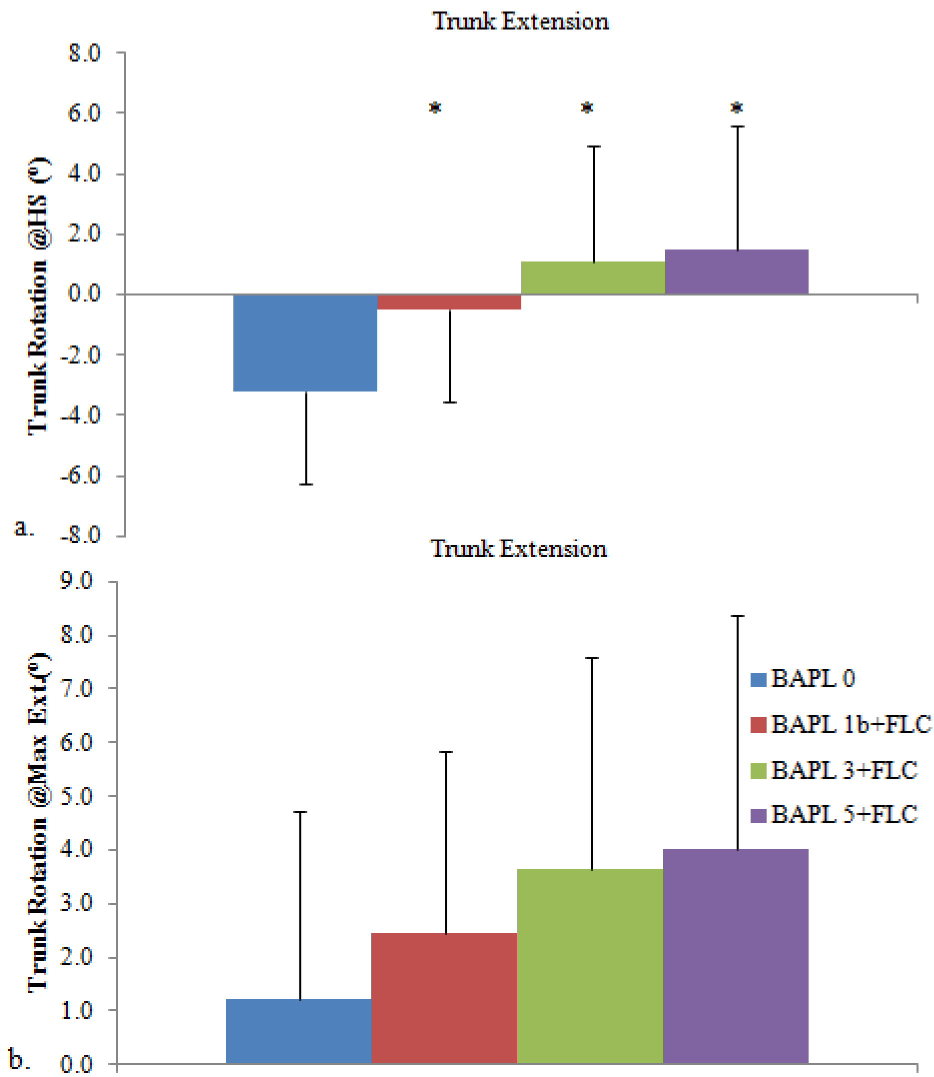
3.2.3.1 Walk

At both HS ($p < 0.001$) and maximum extension ($p < 0.045$), there was a significant effect for BAPL. Specifically, the addition of any body armor significantly increased trunk extension at HS (BAPL 1b+FLC $p = 0.001$, BAPL 3+FLC $p = 0.006$, and BAPL 5+FLC $p = 0.001$) as compared to the no body armor condition (BAPL 0). However, the pairwise comparisons revealed no differences between BAPLs at maximum extension. Additionally there was a significant effect for hip flexion at HS and PS but with no significant pairwise comparisons between BAPLs (Table 14, Figure 17).

Table 14: *Means (SD) of lower limb flexion angles for the walk task: Comparison of BAPLs with FLC to BAPL 0.*

Angle (°)	Position	BAPL 0	BAPL 1b+FLC	BAPL 3+FLC	BAPL 5+FLC
Trunk	HS	-3.2(3.0)	-0.5(3.1)*	1.11(3.8)*	1.5(4.1)*
	Max Ext	1.2(3.5)	2.4(3.4)*	3.7(3.9)*	4.0(4.4)*
Hip	HS	21.5(4.6)	22.2(5.5)	23.2(4.8)	24.4(4.4)
	PS	-13.4(4.5)	-12.0(3.1)	-11.0(4.6)	-10.7(3.5)
Knee	HS	0.8(5.4)	0.7(4.9)	0.4(6.1)	-0.1(5.4)
	PS	-16.1(3.9)	-17.0(3.7)	-17.4(5.1)	-18.0(4.0)

*Significant difference ($p < 0.05$) between BAPL+FLC and BAPL 0



Error bars denote 1 SD.
*Significant difference ($p < 0.05$) between BAPL with FLC and BAPL 0

Figure 17: *Means of trunk flexion angles during walk task: Comparison of BAPLs with FLC to BAPL 0 (a) HS; (b) Maximum extension.*

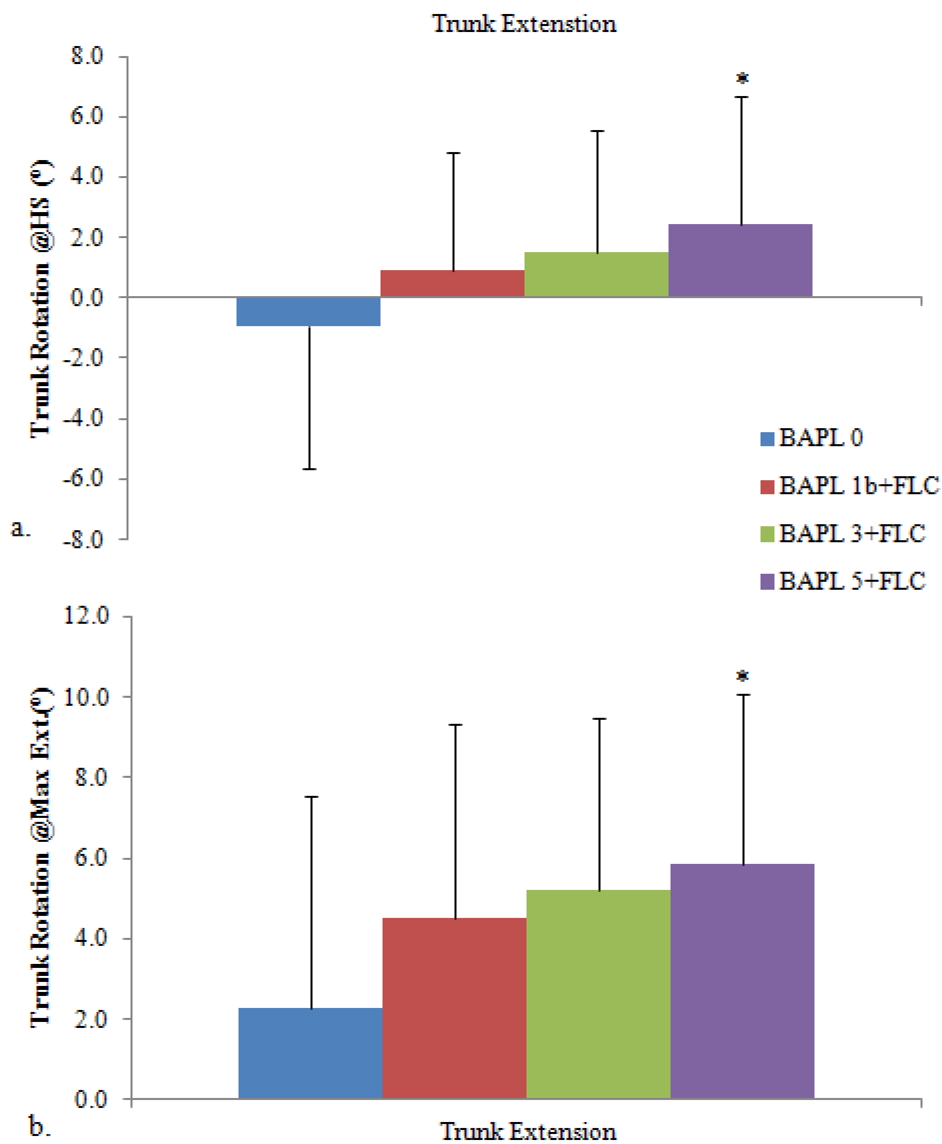
3.2.3.2 Walk Over

The results for all three movements under this task are presented in Table 15. During the walk over task, there was a significant main effect for BAPL +FLC at HS ($p < 0.001$) and maximum extension ($p = 0.005$) for the trunk (Figure 18). Specifically, the Soldiers' trunk had significantly greater extension with BAPL 5+FLC at both HS ($p < 0.001$) and maximum extension ($p = 0.008$) than with BAPL 0. There was also a main effect for BAPL+FLC at the hip at HS (p = 0.016 (Figure 19). The BAPL 3+FLC condition significantly increased the Soldiers' hip flexion (p=0.008, as compared to BAPL 0. There was no effect between any BAPL with FLC and BAPL 0 at the knee.

Table 15: *Means (SD) of lower limb flexion angles for walk over task: Comparison of BAPLs with FLC to BAPL 0.*

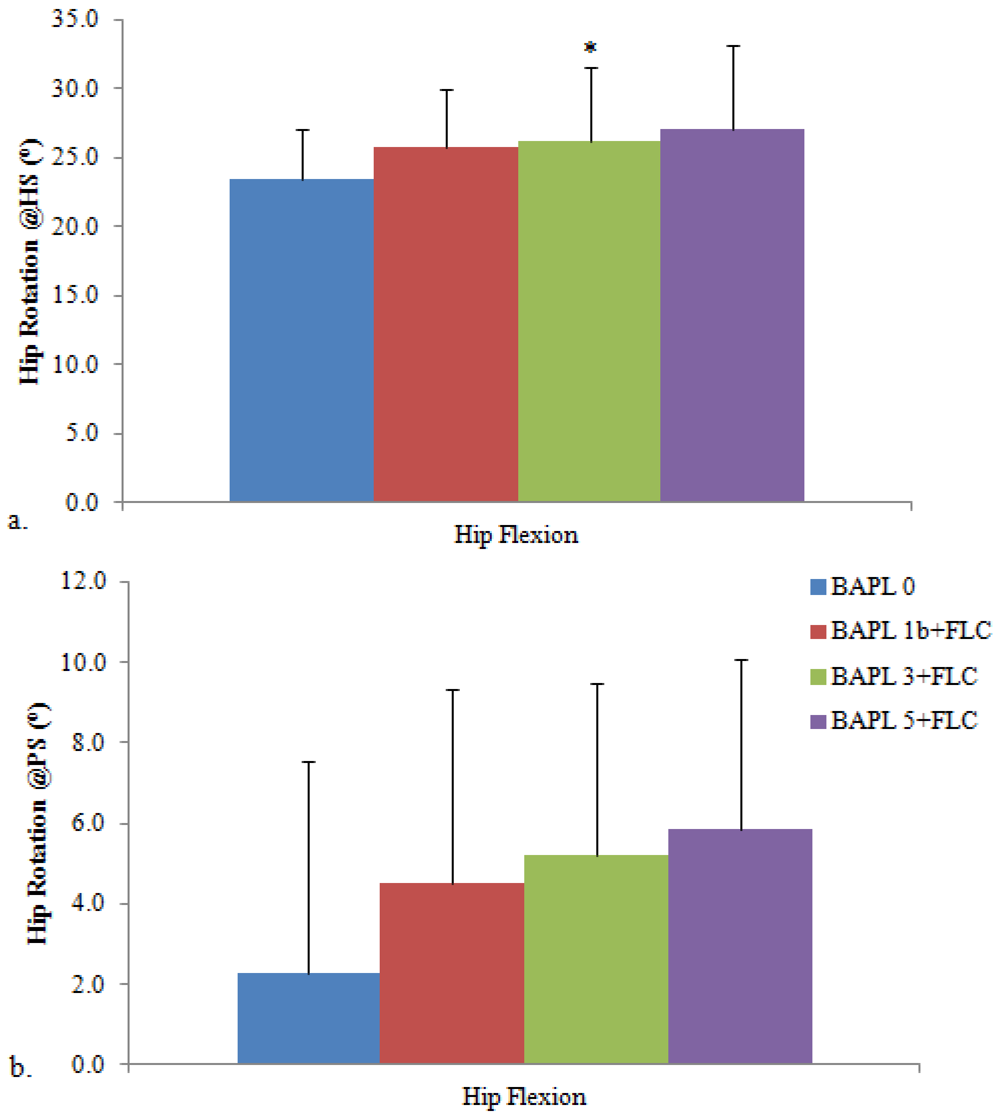
Angle (°)	Position	BAPL 0	BAPL 1b +FLC	BAPL 3+FLC	BAPL 5 +FLC
Trunk	HS	-1.0(4.7)	0.9(3.9)	1.5(4.0)	2.4(4.3)*
	Max Ext	2.3(5.3)	4.5(4.7)	5.2(4.3)	5.9(4.2)*
Hip	HS	23.4(3.7)	25.8(4.1)	26.8(5.4)*	27.0(6.2)
	PS	-13.5(5.6)	-13.9(4.7)	-12.7(4.9)	-12.0(5.2)
Knee	HS	-1.2(6.4)	0.1(6.2)	-0.7(7.0)	-2.3(8.9)
	PS	-17.5(5.2)	-19.4(4.5)	-20.5(6.2)	-20.5(5.6)

*Significant difference ($p < 0.05$) between BAPL with FLC and BAPL 0



Error bars denote +1 SD.
*Significant difference ($p < 0.05$) between BAPL5 with FLC and BAPL 0

Figure 18: *Means of trunk flexion angles during walk over task: Comparison of BAPLs with FLC to BAPL 0. (a) HS, (b) Maximum extension.*



Error bars denote +1 SD.
*Significant difference ($p < 0.05$) between BAPL3 with FLC and BAPL 0 at HS

Figure 19: *Means of hip flexion angles during walk over task: Comparison of BAPLs with FLC to BAPL 0. (a) HS, (b) PS*

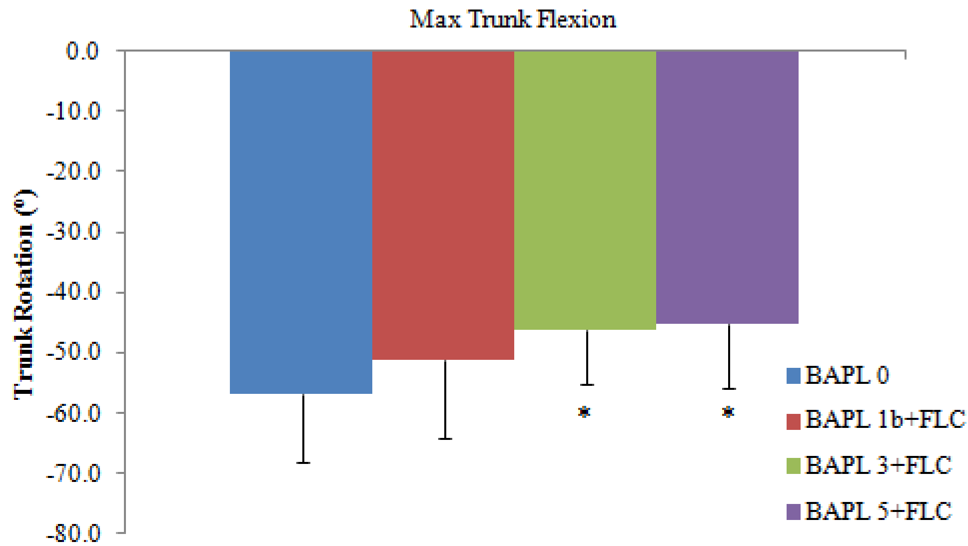
3.2.3.3 Walk Under

For the walk under task, there was a significant effect for BAPL with FLC ($p < 0.001$) (Table 16, Figure 20). Specifically, while wearing BAPL 3+FLC ($p = 0.002$) and BAPL 5+FLC ($p < 0.001$), the Soldiers' maximum flexion significantly decreased as compared to BAPL 0.

Table 16: *Means (SD) of maximum trunk flexion for walk under task: Comparison of BAPLs with FLC to BAPL 0.*

	BAPL 0	BAPL 1b +FLC	BAPL 3+FLC	BAPL 5 +FLC
Trunk (°)	-56.8(11.1)	-51.1(13.1)	-46.3(8.8)*	45.3(10.5)*

*Significant difference ($p < 0.05$) between BAPL with FLC and BAPL 0



Error bars denote 1 SD.
*Significant difference (p < 0.05) between BAPL with FLC and BAPL 0

Figure 20: *Means of maximum trunk flexion during walk under task: Comparison of BAPLs with FLC to BAPL 0.*

3.2.3.4 Balance Beam

There were no significant differences ($p>0.05$) between any BAPL with FLC and BAPL 0 on the balance beam (Table 17).

Table 6: *Means (SD) of HCOM motion for balance beam task: Comparison of BAPLs with FLC to BAPL 0.*

	BAPL 0	BAPL 1b +FLC	BAPL 3+FLC	BAPL 5 +FLC
HCOM (cm)	7.4(2.6)	7.3(2.6)	6.9(0.1)	7.7(3.1)

Note: No significant differences in HCOM between BAPL 0 and any armor condition.

4.0 DISCUSSION

4.1 Consequences of Wearing Body Armor with an FLC

Results from this study showed that the Soldiers' time on the 30 m rush (performance) task decreased significantly between the lightest and heaviest BAPLs evaluated. That is, increasing the weight from 22.6 kg for BAPL 1b to 29.9 kg for BAPL 5 increased total rush time and average individual rush time by 5.3% and 4.5%, respectively. However, significant differences in rush time were not found between the closely weighted BAPLs (BAPL 1b and 3 at 2% or BAPL 3 and 5 at 3%). The current outcomes are in agreement with previous experimental evidence that found Soldiers significantly increased total rush times, by 3.6% between the lightest (19.1 kg) and the heaviest (29.2 kg) body armor conditions for a similar 12 x 5 m rush task, but did not find similar differences in rush time between the other closely weighted armor conditions, with total rush time only increasing between 0.7% - 2.8% (Peoples et al., 2010). The lack of significant differences in rush time between the closely weighted BAPLs currently tested may be due to the symmetric loading of the body with those configurations. Knapik et al (2004) postulated that a symmetric load, distributed close to the body COM, would be less detrimental to Soldier performance on short sprints than asymmetric backpack loading. Increases in load carried have been shown to alter lower limb biomechanics (mobility) and postural stability (postural control); however, these changes have been historically seen with the heavier approach march load between 21 kg and 33 kg (Schiffman et al., 2006, and Harman et al., 1999) or the heaviest emergency approach march load greater than 32 kg (Attwells et al., 2006, and Harman et al., 1999).

Increasing ballistic protection impeded trunk mobility, as demonstrated by a significant 5.8° reduction in the Soldiers' maximum trunk flexion angle while walking under a cross bar at shoulder height. The addition of ballistic plates with BAPL 5 may have limited Soldiers' ability to bend forward at the waist. Passing under obstacles (i.e., a cross bar) may be a likely common Soldier task, but one that has historically been included only with timed obstacle course evaluations (Hasselquist et al., 2012, and Peoples et al., 2010). These studies found that increased load and body armor affect time to complete obstacle courses, but the current study is the first to report on biomechanical changes specifically during a passing under obstacle bar task. The inability to bend forward at the waist with increased protection likely makes the task harder to control and, therefore, may require the Soldier to take more time to complete. This would account for increased time to complete obstacle courses seen within Hasselquist et al., and Peoples et al., as well as explain the increased time to complete the rush task, with increased protection, found in this evaluation. The rush task requires bending at the waist to drop to prone and get back up again. Increased time to overcome an obstacle or drop to cover from fire in combat may lead to vulnerability of the Soldier and diminish his/her lethality or survivability, which may be an area of consideration for future research.

4.2 Consequences of Body Armor with and without FLC on Mobility and Postural Control

The results of this study overwhelmingly show that the addition of the FLC substantially alters Soldiers' trunk, hip, and knee posture, as well as their postural control. In contrast with posterior loading (such as that with a backpack), loading the anterior, with an FLC, forces the Soldier into a more extended position (i.e., leaning backward) during overground walking and

hurdle crossing. Rietdyk et al. (2005) found a similar result when holding a loaded box (anterior loading) during step negotiation. This extended posture is a proactive strategy opposite of that seen in posterior loading, which typically increases trunk flexion with increased loading (Rietdyk et al., 2005). The proactive strategy, whether with anterior or posterior loading, is an effort to maintain the COM within the base of support, which is vital to maintaining upright posture while walking (Harman et al., 1999). Alterations made lower in the kinematic chain, such as the hip flexion angle increase with the addition of the FLC indicated in this evaluation during the walk and walk over tasks, follow the same patterns as with typical load carriage, which has also been identified as an effort to maintain the COM within the base of support (Harman et al., 2000).

Again, this is the first time that kinematics of passing under a cross bar with load carriage has been analyzed. The addition of the FLC to body armor impedes Soldiers' ability to pass under obstacles. The addition of an anterior load, which was not offset by a posterior load, resulted in Soldiers having to maintain an extended trunk posture, i.e., lean backward. Ultimately, this extended posture may impinge their ability to successfully negotiate other obstacles encountered in a range of environments. The examination of load distribution anteriorly and/or posteriorly while passing under low hanging obstacles may be an area of future research to address performance and BAPL tradeoffs.

4.3 Consequences of Wearing Body Armor Protection Compared to Wearing No Armor

When comparing the BAPLs with FLC conditions to the BAPL 0 condition, significant differences in performance and mobility became apparent. Specifically, during the 30 m rush task, both total rush time and individual rush time significantly increased, by 16%-20% and 15%-22%, respectively, when any body armor was worn. Average turn time of the Soldiers also significantly increased by 22.2% while wearing the heaviest body armor (BAPL 5+FLC) compared to the BAPL 0 condition. These results are similar to previous work by Peoples et al. (2010), who found that the addition of any body armor weighing between 19.1 kg and 29.23 kg increased the total 5 m rush time by 3.2% - 7.28% compared to the BAPL 0 condition. These decrements in performance may stem from the changes seen in the biomechanics during the mobility tasks.

During overground walking and walking over the hurdle, the addition of body armor significantly altered trunk posture. For walking, the addition of any body armor significantly increased trunk extension of the Soldiers up to 4.7°. While walking over the hurdle, the Soldiers had increased trunk extension up to 3.6° when wearing the IOTV with all plates and a fighting load (BAPL 5+FLC) compared to the BAPL 0 condition. This is similar to the earlier finding that the addition of the FLC to the body armor during walking and walking over the hurdle also increased trunk extension. The proactive strategy (Reitdyk et al., 2005) of increased trunk extension (i.e., leaning backward) is apparently important to successfully maintaining the COM within the base of support while performing varied mobility tasks and wearing body armor.

As seen earlier with passing under the cross bar, increased body armor protection decreased the Soldiers' ability to bend forward. While wearing either the PC (BAPL 3+FLC) or the IOTV (BAPL 5+FLC) with all plates plus a fighting load, Soldiers' maximum trunk flexion decreased, by 10.6° and 11.5°, respectively, compared to wearing no armor. This inability to bend forward may place a Soldier at risk of contacting low hanging obstacles or may make crouched gait more

difficult. The combination of decreased performance and mobility with incremental increases in body armor protection has the potential to impact a Soldiers' survivability or lethality and may be an area of consideration for future research.

4.4 Considerations

Although data on six mobility tasks were collected, the data for only three tasks were analyzed in order to present concise preliminary findings to date. Further analysis of the remaining mobility tasks may result in statistically significant differences between BAPLs not seen among the three analyzed. For example, the inclusion of the higher height hurdles (46 cm and 61 cm) may amplify biomechanical changes often seen with heavier loads, or may just reinforce the current finding of significant differences only between BAPL 0 and BAPL 5. Furthermore, although data on five BAPLs were collected, results of only four are presented in order to ensure succinct preliminary findings. Further analysis of the remaining mobility tasks and BAPLs may reveal more statistically significant results between BAPLs.

Possible limitations of this evaluation are the constraints placed on speed of walking for the mobility tasks and collection of data for only five of the seven possible BAPLs. The speed was constrained to make sure that biomechanical changes found were due to the change in load, not speed. BAPL 2 and BAPL 4 were not evaluated due to the close proximity in weight to BAPL 3 and BAPL 5, respectively. The disadvantages of these limitations are that the impact of more difficult mobility tasks or increases in load that may impact the speed needed to successfully complete these tasks could not be determined.

Another limitation of this examination is that it focused on the SAW gunner unit position. Given the specificity of load carriage gear by some unit positions, the results found for this evaluation may not be applicable to all dismounted Soldiers. Future researchers may choose to examine the load carrying requirements and interaction of BAPLs for other unit positions on performance, mobility, and postural control.

5.0 CONCLUSIONS

Among the BAPL conditions tested, the largest changes in performance, mobility, and postural control occurred between no armor (BAPL 0) and the full coverage IOTV with all plates (BAPL 5). However, differences among the levels were harder to discern. The results from the tasks examined indicate that the addition of heavy body armor with a fighting load to a Soldier wearing no armor is detrimental to the Soldier. However, when increased protection is necessary for a Soldier already wearing armor, addition of "more" body armor does not significantly decrease performance, mobility, and postural control. That is, in this evaluation no significant differences between BAPL 1 and BAPL 3 or between BAPL 3 and BAPL 5 were seen.

The addition of an FLC to any BAPL significantly decreased Soldiers' mobility and postural control while performing many tasks for each of the three BAPLs. These decreases may be amplified in more strenuous military relevant tasks that are related to react to contact battle drills for infantry units. Future researchers may choose to address an interaction of physical and cognitive performance tasks, such as responding to visual or auditory information while performing mobility tasks. Further research on BAPLs with a fighting load is recommended to examine the remaining BAPLs as part of the BAPL comparison, as well as to examine more challenging and unconstrained mobility and agility tasks in the presence of cognitive performance tasks.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 15/020 in a series of reports approved for publication.

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